Geological Survey
of Canada

Current Research
2000-A6

Reconnaissance geological mapping in southwest Nass River map area, British Columbia

P. van der Heyden, G.J. Woodsworth, and L.D. Snyder

2000

Natural Resources Canada
Ressources naturelles Canada

Canada

Catalogue No. M44-2000/A6E-IN
ISBN 0-660-17998-9

Available in Canada from the
Geological Survey of Canada Bookstore website at:
http://www.nrcan.gc.ca/gsc/bookstore (Toll-free: 1-888-252-4301)

A copy of this publication is also available for reference by depository libraries across Canada through access to the Depository Services Program's website http://dsp-psd.pwgsc.gc.ca. A list of these libraries can be consulted at this site or obtained by calling the toll-free number above.

Price subject to change without notice

Authors' addresses

P. van der Heyden *(pvdh999@aol.com)*
G.J. Woodsworth *(glennw@NRCan.gc.ca)*
GSC Pacific (Vancouver)
101-605 Robson Street
Vancouver, British Columbia V6B 5J3

L.D. Snyder *(snyderl@uwec.edu)*
Department of Geology
University of Wisconsin-Eau Claire
Eau Claire, Wisconsin 54702-4004

Reconnaissance geological mapping in southwest Nass River map area, British Columbia

P. van der Heyden, G.J. Woodsworth, and L.D. Snyder
GSC Pacific, Vancouver

van der Heyden, P., Woodsworth, G.J., and Snyder, L.D., 2000: Reconnaissance geological mapping in southwest Nass River map area, British Columbia; Geological Survey of Canada, Current Research 2000-A6, 9 p. (online; http://www.nrcan.gc.ca/gsc/bookstore)

Abstract: The southwest Nass River (103 P/3, 103 P/4, and 103-O/1) map area is dominated by Upper (?)Jurassic marine sedimentary strata of the Bowser Lake Group and by Eocene granodiorite of the Coast Belt. A large stock of (?)Miocene miarolitic granite outcrops along Observatory Inlet. Remnants of Pleistocene volcanic rocks and the Recent Aiyansh lava flow occur in the eastern part of the area.

Bowser Lake Group strata form a steep-sided, southwesterly tapering prong and were folded about northeast-trending axes. This deformation predates intrusion of the plutonic rocks and may be related to (?)Cretaceous deformation in the Skeena Fold Belt. Westernmost exposures of these strata may have been metamorphosed and deformed in a major, down-to-the-northeast, extensional, ductile shear zone immediately prior to its digestion by Eocene plutons. Granitoid rocks are cut by steeply dipping, northeast-trending faults and fractures and may record late Tertiary extension.

Résumé : La partie sud-ouest de la région cartographique de la rivière Nass (103 P/3, 103 P/4 et 103-O/1) est dominée par des strates sédimentaires marines ((?)Jurassique supérieur) du Groupe de Bowser Lake et par du granodiorite (Éocène) du Domaine côtier. Un gros massif intrusif de granite miarolitique (?)miocène affleure le long de l'inlet Observatory. Des reliques de roches volcaniques pléistocènes et de la coulée de laves récente d'Aiyansh se rencontrent dans la partie est de la région.

Les strates du Groupe de Bowser Lake forment un fourchon aux bords escarpés, effilé vers le sud-ouest, et ont été plissées autour d'axes à orientation nord-est. Cette déformation est antérieure à l'intrusion des roches plutoniques et est peut être associée à une déformation au (?)Crétacé dans la zone de plissement de Skeena. Les affleurements les plus à l'ouest de ces strates ont peut-être été métamorphisés et déformés dans une importante zone de cisaillement ductile par extension avec affaissement vers le nord-est, immédiatement avant sa digestion par des plutons éocènes. Des roches granitoïques, que recoupent des failles et des fractures à pendage raide et à orientation nord-est, pourraient témoigner d'une extension au Tertiaire tardif.

INTRODUCTION

Regional mapping in southwest Nass River map area (Fig. 1) was undertaken in the summer of 1999. Logging roads allowed us to map most of Tseax River map area (103 P/3) at a scale approaching 1:50 000. In the Greenville (103 P/4) and Ashington Range (103-O/1) map areas, roads are few; except for the shoreline and a few ridge traverses, our coverage was restricted to spot helicopter landings, and the scale of mapping is about 1:250 000.

Little bedrock geological work has been done previously in this area, perhaps reflecting the paucity of mineral deposits and generally poor access. Carter (1981) compiled what little was known up to 1974, including unpublished data from exploration companies, but there is no other geological map of the area. Portland Canal, the west border of the Nass River map area, is the site of a seismic experiment, ACCRETE (Morozov et al., 1998).

GEOLOGY

Topographically, the area is transected from northeast to southwest by the Nass River valley (Fig. 2). Observatory Inlet, Portland Canal, and numerous remarkably straight, northeast-trending valleys dominate the western half of the area. Valleys and inlets are steep sided and show ample evidence of modification and deepening by ice. The high country is part of the Coast Mountains and, except for the highest peaks in the southeast corner of the area, was apparently overridden by ice.

The map area encompasses Upper (?)Jurassic sedimentary rocks of the Bowser Basin in the east and Tertiary granitoid and metamorphic rocks of the Coast Belt in the west. Several remnants of Pleistocene volcanic rocks underlie small areas and the Recent Aiyansh lava flow underlies much of the Nass River valley in the eastern part of the map area. The structural grain is dominated by northeast-trending linear features. Sedimentary rocks of the Bowser Basin are folded about northeast- to east-northeast-trending fold axes and granitoid rocks of the Coast Belt are cut by steeply dipping, northeast-trending fractures and dykes. This structural grain and the relative softness of the Bowser Basin sedimentary strata seem to have controlled the southwesterly flow of the Nass River.

Upper Jurassic and Lower (?)Cretaceous Bowser Lake Group

Sedimentary rocks consisting of intercalated grey sandstones and dark grey to black siltstone and mudstone underlie most of the Tseax River map area and extend as a southwest-tapering prong into the southeastern Greenville map area (Fig. 2). These rocks are continuous with similar sedimentary rocks of the Bowser Lake Group that are widely exposed north, east, and south of the map area (Evenchick and Mustard, 1996; Evenchick and Holm, 1997; Gareau et al., 1997). Their

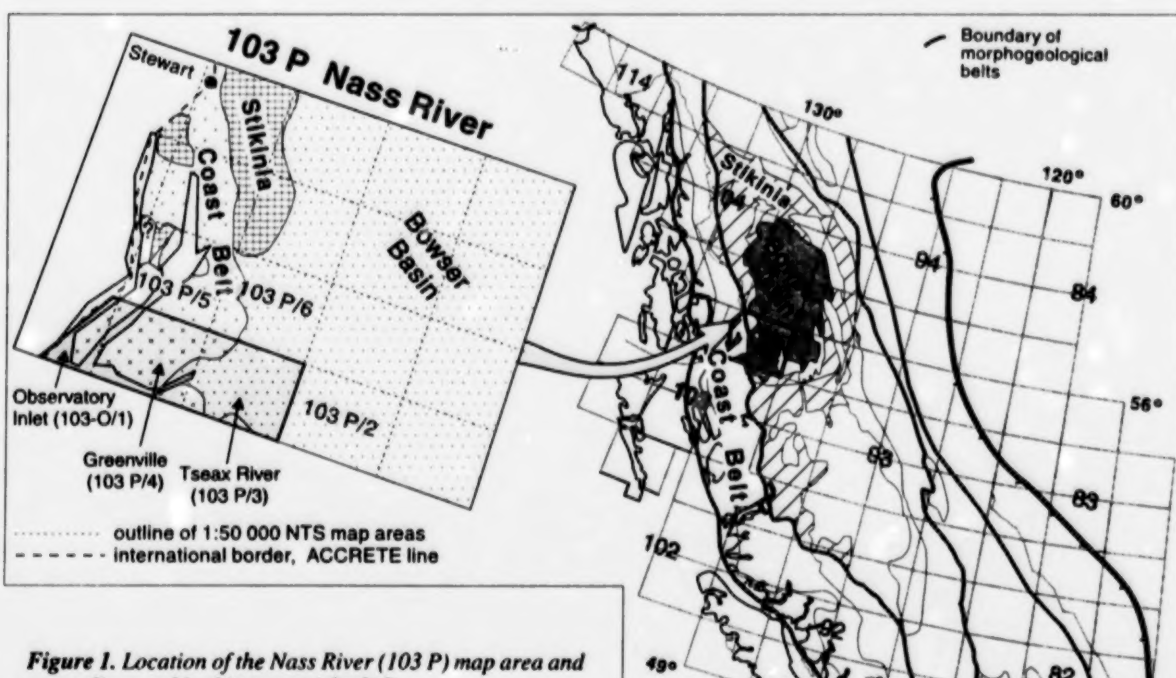

Figure 1. Location of the Nass River (103 P) map area and areas discussed in this report (shaded).

characteristic rusty brown weathering contrasts sharply with the grey and white of surrounding plutonic rocks. The intrusive contact between these two dominant units is visible from a distance and is relatively easy to map. The sedimentary rocks adjacent to plutons are commonly hornfelsed.

In the Tseax River and Greenville map areas, these rocks make up a single unit of monotonous, thin- to thick-bedded sandstone and siltstone turbidites interbedded with mudstone sequences. Discontinuous road outcrop, open to tight, locally overturned folds, and local repetition by thrust faults obscure the stratigraphy; the total thickness is difficult to estimate, but probably exceeds 1000 m. Individual beds seem to be continuous over tens to possibly hundreds of metres and range up to tens of metres in thickness, with the thicker beds representing amalgamated units. Sedimentary structures include basal scour and flame structures, rare flute and groove marks, load casts, planar lamination, truncated ripple stratification, angular rip-up clast horizons, and T_{AE}, T_{ABE}, T_{ABCE}, and rare T_{ABCDE} Bouma sequences. Beds are commonly smoothly graded from medium-grained sandstone to fine-grained siltstone and mudstone. Massive, structureless sandstone predominates, but planar-laminated sandstones are not uncommon.

Most sandstones are lithic arenites consisting predominantly of fine- to medium-grained chert fragments. Rare and inconclusive paleoflow indicators suggest either a northeast- or southwest-directed paleoslope. To the northeast, similar sandstones were derived from an eastern source area (Evenchick and Mustard, 1996). In the Greenville and western parts of the Tseax River map areas, many of the sandstones are composed largely of medium- to coarse-grained, angular feldspar grains. These immature sandstones must have been derived from a nearby volcanic source region. They are probably correlative with similar material exposed in the adjacent Alice Arm map area for which a possible western source has been suggested (Evenchick and Mustard, 1996). The feldspathic sandstones and the chert-rich arenites may interfinger laterally and/or there may be a vertical stratigraphic transition from one to the other.

The sandstones in our study area are probably mostly gravity-flow turbidites that were deposited in deep shelf or slope submarine-fan environments; amalgamated, thick-bedded sandstones may be density-modified grain flows, similar to sandstones north and northeast of the study area (Evenchick and Mustard, 1996). Southeasternmost exposures of strata in the Tseax River area consist entirely of black mudstone and rare siltstone. These fine-grained clastic rocks may represent a distinct facies of the Bowser Lake Group, possibly similar to deep-water shelf environments suggested for fine-grained clastic rocks farther northeast (Haggart et al., 1998).

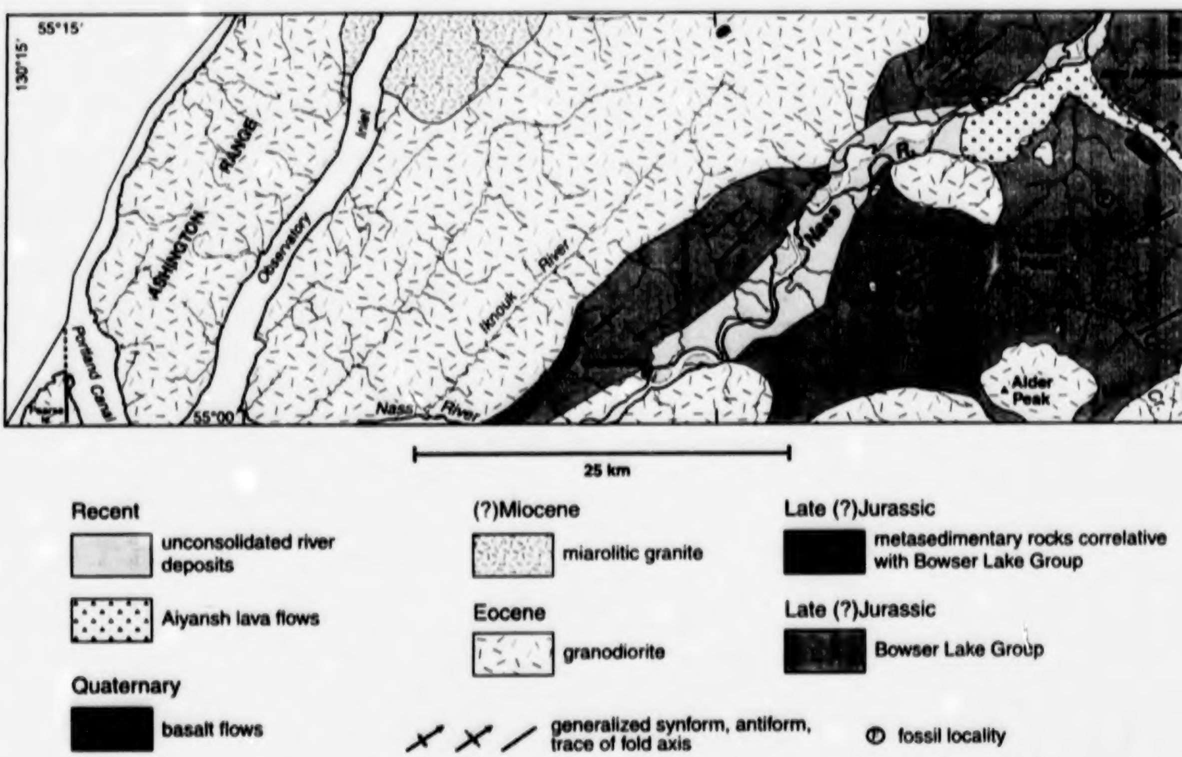

Figure 2. *Generalized geological map of the Tseax River (103 P/3), Greenville (103 P/4), and Ashington Range (103-O/1) map areas.*

Four new fossil localities were found in this unit (Fig. 2), three in cleaved argillite and one in fine-grained sandstone. The fossils are poorly preserved and deformed, but two collections (GSC Loc. C-304501 and C-304502) contain buchiid bivalves of probable Late Jurassic (possibly Late Tithonian) age and a third collection (GSC Loc. C-304503) suggests a Late Jurassic to possibly Early Cretaceous age (J.W. Haggart, unpub. GSC fossil report JWH-1999-05, 1999). Several other locations not shown on Figure 2 contain very poorly preserved bivalves; a few poorly preserved belemnite casts and moulds were found near Alder and May creeks.

Eocene plutonic rocks

Plutonic rocks of the Coast Belt occupy part of the Tseax River and almost all of the Greenville and Ashington Range map areas. Granodiorite underlies almost the entire western half of the map area and is continuous with the Eocene Hyder pluton north of the map area (Evenchick, 1996; Evenchick et al., 1997b). Granodiorite in the southeastern Greenville and southern Tseax River map areas forms the northern margin of the Eocene Ponder pluton (Hutchison, 1982), samples of which from the mouth of the Nass River immediately south of our area gave ca. 50 Ma zircon U-Pb dates (L.S. Hollister, pers. comm., 1999).

The Hyder and Ponder plutons coalesce at the mouth of the Nass River near the southwest end of the prong of Bowser Lake Group rocks. They may also join beneath the Bowser Lake Group in the Tseax River map area. In the areas surrounding Vetter Peak and Canyon City, the Bowser Lake Group is extensively invaded by north- to north-northwest-trending granitoid dykes and associated felsic stocks, many of which extend out from the nearby plutons. These intrusions seem to be a high-level expression of a north-northwest-trending plutonic bulge that is exposed as the larger stocks south of Canyon City and on Alder Peak.

The granodiorite is typically grey weathering, light grey to white, medium grained, and contains 5–25% biotite hornblende and common accessory titanite. Compositional variations include irregular domains of granite, tonalite, quartz monzonite, quartz monzodiorite, and quartz diorite. The rock is locally strikingly K-feldspar megacrystic. It is unfoliated and relatively homogeneous, except in the southwestern part of our area, where it is commonly moderately to strongly foliated and contains lenticular mafic inclusions, mafic schlieren, and numerous gneissic screens. Larger gneissic domains are distinguishable at 1:50 000 scale, but were not mapped in any detail. Foliation, defined primarily by alignment of mafic minerals and by thin, discontinuous, mafic schlieren, apparently represents flow layering rather than a tectonic fabric, but locally the rock is best described as an orthogneiss, with the implication of a tectonic origin. The granodiorite is clearly late kinematic with respect to ductile deformation in the gneissic screens.

Several generations of leucocratic dykes and veins are present in the granodiorite and the gneissic screens. They range from fine-grained aplite to very coarse-grained quartz-feldspar pegmatite and from granite to quartz diorite. No conspicuous preferred orientation trends were noted.

Several small granitoid stocks intrude the Bowser Lake Group and the granodiorite pluton in the Tseax River map area. These include porphyritic quartz monzonite, quartz-feldspar porphyry, and tonalite and are associated with small mineral occurrences (Carter, 1981). Molybdenum and copper mineralization in these stocks occurs mainly in northeast- and northwest-trending fractures and quartz veins. The host stocks are mostly satellitic to the main granodiorite plutons, but locally they intrude the plutons and are in turn cut by younger granitoid and quartz-feldspar porphyry dykes. Carter (1981) related the mineralized stocks to the economically significant, 49–55 Ma, Alice Arm intrusions north of the map area. The stocks, their associated mineralization, and the crosscutting granitoid and porphyritic dykes are here inferred to reflect late stages of Eocene plutonism, with the larger granodiorite pluton representing the main phase.

Metamorphic screens

The prong of Bowser Lake Group rocks in the southeastern Greenville map area can be viewed as a large, steep-sided, metasedimentary screen that opens to the northeast. It increases in metamorphic grade to the southwest, but does not extend across the Nass River south of the map area. Northeast of Greenville, the sedimentary rocks are merely hornfelsed. North of Greenville, they are contact-metamorphosed to low amphibolite facies, but sedimentary structures and bedding are well preserved. West and southwest of Greenville, the rocks are quartz-feldspar-biotite schists with locally well developed, ductile fabrics that have completely transposed the original sedimentary layering. Within a few hundred metres of the pluton contact, which parallels the ductile foliation, the metamorphic fabric of these metasedimentary rocks is annealed and the rocks have been invaded by late- to post-kinematic granodiorite sills and dykes. The sills have no obvious fabric, but they are strung out and pinch and swell in the foliation plane. Calcareous concretions, common in Bowser Lake Group sandstones throughout the map area, are metamorphosed to calc-silicate knots that are deformed into large boudins with ductile stretching tails. These relations suggest that westernmost exposures of bona fide Bowser Lake Group were metamorphosed and deformed in a ductile shear zone immediately prior to invasion by Eocene plutons.

Identical features are present and identical conclusions can be drawn from kinematic relations in isolated screens of rusty-brown-weathering metasedimentary schist and gneiss enclosed within the Eocene granodiorite as far west as Observatory Inlet. These are tabular to lenticular bodies up to several hundred metres thick. Most of the metasedimentary screens are of amphibolite facies: they are gneissic rather than schistose and commonly contain metamorphic garnet and amphibole. Tight to isoclinal folds are common and syn- to late-kinematic granitoid sills commonly show boudinage. Calc-silicate knots and augen, similar to those observed in bona fide Bowser Lake Group metasedimentary rocks west of Greenville, locally form a characteristic component of these gneisses. They are almost certainly metamorphosed Bowser Lake Group rocks and we interpret them as fragments of the same ductile shear zone exposed west of Greenville, now engulfed in the Eocene pluton.

A second variety of gneissic screen material is present in the southwestern part of the map area. These rocks are mafic, medium- to coarse-grained, commonly migmatitic, banded biotite-feldspar-quartz gneiss and foliated amphibolite. The same material occurs as smaller, equigranular xenoliths and lenticular schlieren throughout the granodiorite pluton. Locally, these mafic rocks form larger, irregular domains that are invaded by an agmatitic granodiorite stockwork. Identical migmatitic gneissic rocks immediately south of the map area in Nass Bay include bands of leucogneiss, but this was not observed in our area. Structurally, the mafic gneiss screens share many ductile kinematic features with the metasedimentary gneiss screens, but they were probably derived from entirely different protoliths, possibly from compositionally diverse volcanic rocks. Collectively, the magmatic and structural features of the mafic gneiss screens suggest that the screens represent fragments of a high-grade, ductile shear zone that was undergoing partial melting immediately prior to being digested by Eocene plutons.

(?)Miocene granite

Coarse-grained, massive granite intrudes the Eocene granodiorite along Observatory Inlet in the northern part of the map area. This granite typically weathers white and contrasts with the surrounding grey granodiorite, which it clearly intrudes and into which it projects abundant dykes several hundred metres away from the contact. The granite contains up to 15% fresh biotite; hornblende and titanite are rare. It includes some quartz monzonite and alkali-feldspar granite; locally, it is miarolitic and contains minor muscovite and garnet. Except for small, scattered, mafic xenoliths, the granite is homogeneous. It appears to form a subrounded stock about 10 km in diameter. Evenchick et al. (1999) recognized the presence of biotite granite along Observatory Inlet, but did not differentiate it from the Hyder pluton. The similarity of this granite to Miocene plutons along northern Portland Canal and Portland Inlet (Evenchick et al., 1999; R.M. Friedman, pers. comm., 1999) and the clearly intrusive contact with the granodiorite suggest that the granite is relatively young.

Mafic dykes

Mafic dykes are common in both granodiorite and granite in the western part of the map area. Most are dark grey to black and dioritic to gabbroic. Aphanitic dykes are most common, but many are porphyritic with chilled margins. Phenocrysts include plagioclase, pyroxene, amphibole, and rare olivine. Almost all mafic dykes are tabular and range in width from a few centimetres to 10 m. Most dykes trend north-northeast, parallel to ubiquitous fractures and regional lineament trends. This trend is believed to reflect Miocene extensional kinematics (Evenchick et al., 1999). Rhyolite dykes at the north end of Pearse Island intrude and are cut by a major, north-trending, brittle fault zone. They seem to be genetically associated with the more common mafic dykes, suggesting a common bimodal source.

Pleistocene and Recent volcanic strata

Columnar-jointed basalt and basalt breccia form three conspicuous erosional remnants draping the slope of a glacial valley in the extreme northwest corner of the Tseax River map area. They are each about 200 m across and rest nonconformably on granodiorite. These erosional remnants are glacially grooved and striated and have only recently been exposed from under a nearby glacier. Similar basalt farther northeast was dated at 175 000 ± 50 000 years (Evenchick et al., 1997a) and we assume that the erosional remnants in the Tseax River map area are the same age. These Pleistocene volcanic remnants lie along the Iknouk River topographic lineament, one of several pronounced, northeast-trending, topographic lineaments in the map area. These lineaments reflect preferential erosion of northeast-striking Miocene fractures and apparently provided conduits for both Miocene and Pleistocene basaltic magmas. It is interesting to note that hot springs at Burton Creek, in the Kincolith (103-I/13) map area, are situated along the southwesterly extension of the Iknouk River topographic lineament.

A 1.2 km^2 exposure of vesicular, olivine-phyric basalt about 5 km south-southwest of New Aiyansh is interpreted as an erosional remnant of a Pleistocene flow that occupied a pre- or interglacial valley of the Tseax River. It is at least 10 m thick and rests disconformably on mudstone of Bowser Lake Group, on a bench about 150 m above the Tseax River. Similar material is present 10 km southeast in the Lava Lake (103 P/2) map area (J.W. Haggart, pers. comm., 1999) and there is a report of 'older' basalt about 8 km west of Canyon City, 150 m above the valley bottom along the north side of Nass River and well beyond the front of the Aiyansh flow (H. Smith, pers. comm., 1999). These occurrences of volcanic rock lie topographically above and are all clearly older than the approximately 600 to 220 year old Aiyansh flows. Their distribution suggests that the Aiyansh flows were preceded by one or more pre- or interglacial flows that may have originated from the same general vent area.

STRUCTURAL GEOLOGY

Sedimentary rocks of the Bowser Lake Group are folded about northeast- to east-northeast-trending fold axes. Orientations of opposing limbs indicate that these axes plunge gently to the northeast (Fig. 3a). The folds are open to tight and locally overturned to the southeast; folds overturned to the northwest are less common. Wavelength is on the order of hundreds of metres to about 1 km. Axial planar cleavage (Fig. 3b) ranges from none to a poorly developed, widely spaced fracture cleavage to very closely spaced slaty cleavage and phyllite. Minor parasitic folds are present in some places, locally with development of an incipient transposition fabric parallel to the cleavage. Evidence for southeast-vergent thrusting parallel to axial planes was observed in the limbs of a few overturned folds.

The age of folds and thrusts in the map area is poorly constrained. As they are cut by granitoid dykes related to the granodiorite pluton, they are pre-Eocene, probably Mesozoic

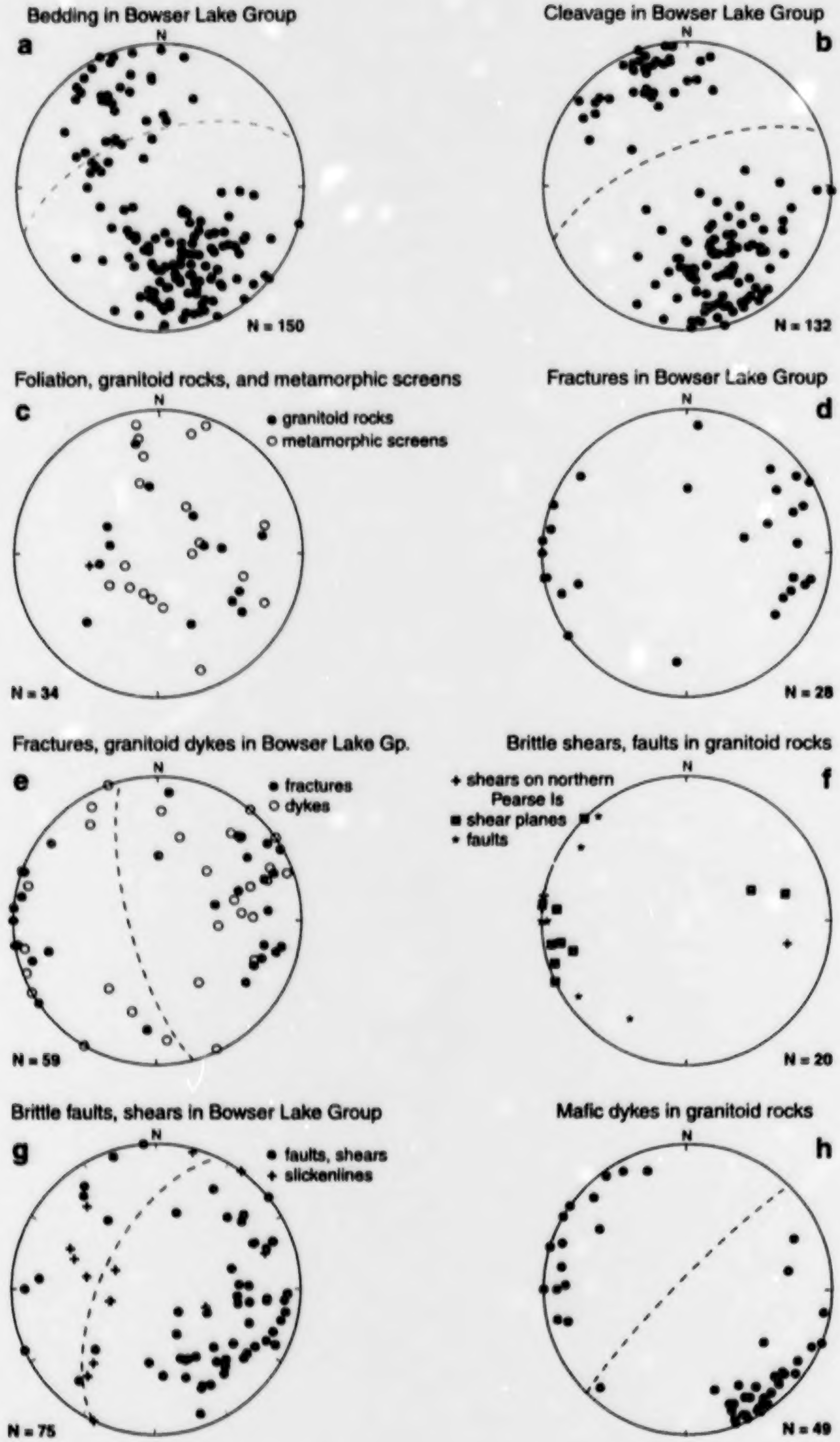

Figure 3. Lower hemisphere, equal-area projections of structural features in the southwest Nass River area. N is the total number of data points for each diagram.

structures, but the folds may have been tightened by pluton intrusion. Fold trends are continuous with trends in neighbouring areas to the north (Evenchick and Mustard, 1996), northeast (Haggart et al., 1998), and east (J.W. Haggart and J.B. Mahoney, pers. comm., 1999). These trends swing around to the north and northwest in the eastern Nass River map area (J.W. Haggart, pers. comm., 1999), where they are clearly related to the Late Cretaceous, northeast-vergent Skeena fold and thrust belt. Folds and thrusts in the Tseax River and Greenville map areas are therefore tentatively assigned a Late Cretaceous age. The northeasterly trend seems to be developed strongly only near the southern margin of the Bowser Basin and may reflect some sort of basement structural control.

Westernmost outcrops of Bowser Lake Group in the Greenville map area were subjected to strong ductile shear under greenschist-facies conditions prior to intrusion of the granodiorite plutons. The origin of these metamorphic and structural features is not clear: they are undoubtedly related to pluton emplacement in a general way, but this relationship is not necessarily a directly causal one. It is possible, for instance, that the pluton represents a decompression melt generated in the footwall of a crustal-scale extensional shear zone, with the ductile-sheared Bowser Lake Group representing a deformed domain of the upper plate. Such an interpretation is not inconsistent with local geological features nor with regional geochronological and tectonic observations (Hollister and Andronicos, 1997; Heah, 1991).

Structural features of gneissic screens in the granodiorite pluton, as discussed previously, suggest that the screens formed in a ductile shear zone under amphibolite-facies conditions. Rotational and linear kinematic indicators in the gneissic screens suggest a top-to-the-northeast sense of shear; similar observations have been made along the Nass River immediately south of the map area (L. Hollister, pers. comm., 1999). In the western part of the map area, foliations in the gneissic screens and in the pluton are generally gently dipping (Fig. 3c), leading to the regional impression of a warped, but overall subhorizontal, gneissic slab invaded and flooded by a sill-like pluton. Kinematic relations between gneiss and plutonic rock suggest that the pluton engulfed a top-to-the-northeast ductile shear zone during the waning phases of deformation. The late- to post-kinematic invasion of ductile fabrics in both gneissic screens and the westernmost Bowser Lake Group by the same granodiorite suggests that these fabrics may have formed in the same ductile shear zone. Unambiguous kinematic indicators were not observed in the western Bowser Lake Group in the course of our brief study, but the available evidence from mesoscopic rotational features is consistent with a top-to-the-northeast ductile shear zone that was overturned to the southeast by plutonic bulging.

Brittle structural features in the map area include several fracture sets and numerous minor brittle faults (Fig. 3d–g). These generally steeply dipping features parallel distinctive topographic lineaments in the western part of the map area. Most notable among these are deeply scoured, northeast-trending, linear valleys and inlets. A brief examination of the pass at the head of the Iknouk River indicates the presence of a few steeply dipping, northeast-trending fractures and brittle shears, some of which have affected slightly older, northeast-trending, mafic dykes, but no major fault is present here. The widespread occurrence of mafic dykes parallel to these and other topographic lineaments (Fig. 3h), in both granodiorite and younger granite suggests that they are related to relatively young Tertiary extension. Similar features north of the map area were previously inferred to be related to several episodes of Early Miocene or younger extension (Evenchick et al., 1999).

To the north, Evenchick et al. (1999) postulated the presence of two major brittle extensional faults, the Portland Canal and Big Dam faults, striking 350° and projecting into our map area. Although steeply dipping, north- to north-northwest-trending fractures and cataclastic shear zones are present in both plutons in our area, no evidence was encountered for the southern extensions of these faults. The only major brittle fault encountered during our field work is a 1–2 km wide, north-trending, steeply dipping, brittle shear zone exposed along the north shore of Pearse Island. Evenchick et al. (1999) identified and interpreted this shear zone as an early Miocene extensional fault. It is characterized by wide bands of cohesive fault breccia containing angular fragments of granodiorite as well as mafic and felspar-porphyry dyke fragments. The breccias are invaded by younger mafic and felsic dykes (including rhyolite) and by feldspar-porphyry dykes and all are cut by north-trending fractures and narrow, cataclastic shear bands. These features support the suggestion by Evenchick et al. (1999) that the dykes may constrain the timing of faulting. In addition, their bimodal nature suggests that they may belong to a chemically distinct extensional suite.

An older set of steeply dipping, north- to northwest-trending fractures apparently accommodated the emplacement of early Tertiary granitoid dykes in the Canyon City–Vetter Peak–Alder Peak area (Fig. 3h). This structural trend is therefore considerably older than the Early Miocene and younger fractures and faults farther west. These older structures and associated dykes are similar and may be related to the ca. 52 Ma Larcom dyke swarm (Evenchick et al., 1999) and the ca. 50 Ma Portland Canal dyke swarm (Green et al., 1995) northwest of the map area.

DISCUSSION

The southwest Nass River map area is dominated by Upper (?)Jurassic marine sedimentary rocks of the Bowser Lake Group that were folded about northeast-trending axes and form a southwesterly tapering pendant underlain, partly enclosed, and extensively invaded by early Tertiary granitoid plutonic rocks of the Coast Belt. These rocks represent the most southwesterly exposures of the Late Jurassic Bowser Basin, which received detritus from eastern sources; a western margin of the basin has never been identified. Most of the strata in the study area resemble Bowser Lake Group strata elsewhere in northern British Columbia and likewise were probably derived from eastern source terranes. Distinctive feldspathic sandstones, also present to the north in the Alice Arm (103 P/6) and Observatory Inlet (103 P/5) map areas, are

a possible exception. The feldspathic sandstones differ markedly from the more lithic, chert-rich sandstones characteristic of the Bowser Lake Group elsewhere and were clearly derived from a proximal volcanic source terrane. Paleocurrent indicators in the Alice Arm map area suggest a western source; rare paleocurrent indicators in our map area are equivocal. Westernmost exposures of feldspathic Bowser Lake Group rocks, well exposed on ridge crests north of Greenville, may provide further clarification with additional work.

West and southwest of Greenville, the Bowser Lake Group was subjected to intense ductile shear under greenschist-facies conditions immediately prior to pluton intrusion. This area may represent a short segment of the upper, greenschist-facies part of a ductile extensional shear zone, which was elsewhere engulfed and partly digested by Eocene granodiorite. The granodiorite contains metamorphic screens, derived in part from the Bowser Lake Group, which preserve evidence of Eocene ductile shear under amphibolite-facies conditions. These features are consistent with a major, down-to-the-northeast, ductile, extensional shear zone with Bowser Lake Group in the upper plate and early Tertiary, migmatitic gneiss in the lower plate. Ductile extensional shear between Eocene migmatitic gneiss of the Coast Belt to the west and lower grade rocks of the Intermontane Belt to the east, including Bowser Lake Group strata, has been well documented south of the map area near Terrace (Heah, 1991; Hollister and Andronicos, 1997). We propose that the extensional shear zone near Terrace extends northwest into our map area, where it was almost completely engulfed by the Eocene Ponder and Hyder plutons and within which it is only partly preserved as relict xenolithic screens. The presence of large, late- to post-kinematic plutons straddling the trajectory of a major extensional shear zone and their lithological similarity to migmatitic leucosome in the gneissic screens suggest that the Ponder and Hyder plutons may have been derived, at least in part, from decompression melting of the lower plate.

Early Tertiary and younger brittle extension is documented by the regional presence of distinct fracture sets and associated granitoid and mafic dykes and by a major local shear zone and associated mafic and felsic dykes. The brittle structures in our map area are consistent with the interpretation by Evenchick et al. (1999) of Eocene northeasterly and northwesterly extension followed by Miocene or younger east-west extension. East-west extension may have been accommodated on a regional scale by the development of en échelon grabens localized along and slightly east of the trajectory of the Eocene ductile extensional shear zone. The Big Dam and Portland Canal faults (Evenchick et al., 1999) may be scissor faults that bound a southerly discontinuous graben; southeast of the map area, the northerly discontinuous Kitsumkalum graben (Woodsworth et al., 1985) may represent the en échelon continuation of east-west extension.

ACKNOWLEDGMENTS

We thank Betty and Bill Geier of Rosswood, British Columbia, for hospitality and warmth (especially on the many bleak, rainy days), Carl Healy, Tony Walker, and Darrell Adzich for safe helicopter flights, and Mike Schmidt, Gloria Roth, and David Woodsworth for cheerful assistance. Harold Smith of Terrace, British Columbia, provided stimulating discussion of local geology and directed us to the older lavas along the Tseax and Nass rivers. Mr. Jacob McKay of the Nisga'a tribal government is sincerely thanked for his counsel and interest in our scientific work. Discussions with Lincoln Hollister, Jim Haggart, and Brian Mahoney and a review of the manuscript by Jim Haggart were very helpful.

REFERENCES

Carter, N.C.
1981: Porphyry copper and molybdenum deposits, west-central British Columbia; British Columbia Ministry of Energy, Mines, and Petroleum Resources, Bulletin 64, 150 p.

Evenchick, C.A.
1996: Geology, Alice Arm, British Columbia (103P/6); Geological Survey of Canada, Open File 3272, scale 1:50 000.

Evenchick, C.A. and Holm, K.
1997: Bedrock geology of the Anyox pendant and surrounding areas, Observatory Inlet (103P/5) and parts of Hastings Arm (103P/12) and 103O/9 map areas, British Columbia; *in* Current Research 1997-A; Geological Survey of Canada, p. 11–20.

Evenchick, C.A. and Mustard, P.S.
1996: Bedrock geology of north-central and west-central Nass River map area, British Columbia; *in* Current Research 1996-A; Geological Survey of Canada, p. 45–55.

Evenchick, C.A., Alldrick, D.J., Currie, L.D., Haggart, J.W., McCuaig, S., McNicoll, V., and Woodsworth, G.J.
1997a: Status of research in the Nass River multidisciplinary geoscience project, British Columbia; *in* Current Research 1997-A; Geological Survey of Canada, p. 21–30.

Evenchick, C.A., Crawford, M.L., McNicoll, V.J., Currie, L.D., and O'Sullivan, P.B.
1999: Early Miocene and younger normal faults and other Tertiary structures in west Nass River map area, northwest British Columbia, and adjacent parts of Alaska; *in* Current Research 1999-A; Geological Survey of Canada, p. 1–11.

Evenchick, C.A., McNicoll, V.J., Holm, K., Alldrick, D.J., and Snyder, L.D.
1997b: Geology, Anyox pendant and surrounding areas in Observatory Inlet (103P/5) and parts of Hastings Arm (103P/12), 103O/8 and 103O/9, British Columbia; Geological Survey of Canada, Open File 3454, scale 1:50 000.

Gareau, S.A., Woodsworth, G.J., and Rickli, M.
1997: Regional geology of the northeastern quadrant of Terrace map area, west-central British Columbia; *in* Current Research 1997-A; Geological Survey of Canada, p. 47–55.

Green, D., Greig, C.J., and Friedman, R.M.
1995: Portland Canal dyke swarm, Stewart area, northwestern British Columbia: geologic setting, geochronology, and thermal modelling; *in* Current Research 1995-E; Geological Survey of Canada, p. 47–57.

Haggart, J.W., Woodsworth, G.J., and Justason, A.
1998: Update on geological mapping, southeast Nass River map area, British Columbia; *in* Current Research 1998-A; Geological Survey of Canada, p. 69–77.

Heah, T.S.T.
1991: Mesozoic ductile shear and Palaeocene extension along the eastern margin of the Central Gneiss Complex, Coast Belt, Shames River area, near Terrace, British Columbia; M.Sc. thesis, University of British Columbia, Vancouver, British Columbia, 155 p.

Hollister, L.S. and Andronicos, C.L.
1997: A candidate for the Baja British Columbia fault system in the Coast Plutonic Complex; GSA Today, v. 7, no. 11, p. 1–7.

Hutchison, W.W.
1982: Geology of the Prince Rupert–Skeena map area, British Columbia; Geological Survey of Canada, Memoir 394, 116 p.

Morozov, I.B., Smithson, S.B., Hollister, L.S., and Diebold, J.B.
1998: Wide-angle seismic imaging across accreted terranes, southeastern Alaska and western British Columbia; Tectonophysics, v. 299, p. 281–296.

Woodsworth, G.J., Hill, M.L., and van der Heyden, P.
1985: Geology, Terrace, B.C. 103I east half; Geological Survey of Canada, Open File 1136, scale 1:125 000.

Geological Survey of Canada Project 950037